Monitoring and Control of Power Systems and Communication Infrastructures based on IEC 61850 and IEC 61400-25

Karlheinz Schwarz, SCC
Karlsruhe/Germany

schwarz@scc-online.de

http://iec61850-news.blogspot.com

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1 Introduction

The focus of the first edition of IEC 61850 "Communication networks and systems in substations" was on substation operational aspects (mainly protection and control). Various groups have identified that IEC 61850 is the basis of further applications, e.g., monitoring of functions, processes, primary equipment, and the communication infrastructure in substations and other power system application domains. The second edition of the first 14 parts IEC 61850 (with the new title "Communication networks and systems for power utility automation") and other extensions provide further definitions to keep the high quality and availability of power systems, to reduce commissioning time and life cycle costs.

Edition 2 of IEC 61850 provides new data objects for (condition) monitoring. Many new data objects are added for critical measurements like temperatures, oil levels, gas densities, maximum number of connections exceeded et cetera. Such extensions cover the monitoring of equipment like switchgear, transformers, on-load tap changers, automatic voltage regulation devices, gas compartments, and lines; generators, gearboxes, and towers in wind turbines; communication infrastructure like Ethernet switches and routers. Myriads of sensors are needed to monitor the condition of the wind power foundation, tower, rotors, gearboxes, generators to name just a few. The standard IEC 61400-25-2 extends IEC 61850 with condition monitoring data objects for wind turbines. IEC 61850-7-4 (core information models), IEC 61850-7-410 (extensions for hydro power plants), IEC 61850-7-420 (decentralized energy resources), and IEC 62351-7 (security) provide a huge list of new data objects for general monitoring purposes.

The abstract data objects are the basis for a sustainable interoperability in the power industry – abstract means, they can be mapped to more than protocol; sustainable means, they can be used "forever". The abstract objects can be mapped to MMS as defined in IEC 61850-8-1 or (according to IEC 61400-25-4) to Web Services, OPC-XML, IEC 60870-5-10x, or DNP3.

The new extensions are a pivotal point for the interoperability of exchanging monitoring information in the future electric power systems – they can make the power systems smarter than they were in the past. This paper presents and discusses the benefits and challenges of the various model extensions in edition 2 of IEC 61850 and other related standards. Realizations in practical use in power utilities will be presented, too.

2 Information modeling in IEC 61850

Information models are one of the key elements of the standard series IEC 61850 and related standards. Information models represent measurements and status information taken at the process level, and other kinds of processed information like metering information. The information models are independent of any communication protocol and network solution. They are intended to have a "long life" – a Phase C Voltage in a 50 Hz system is a Phase C Voltage today, tomorrow, in 20 years, in Karlsruhe and in Reykjavik.

Figure 1 shows the different levels of standard definitions: from "long-life" at the top to "short-life" at the bottom.

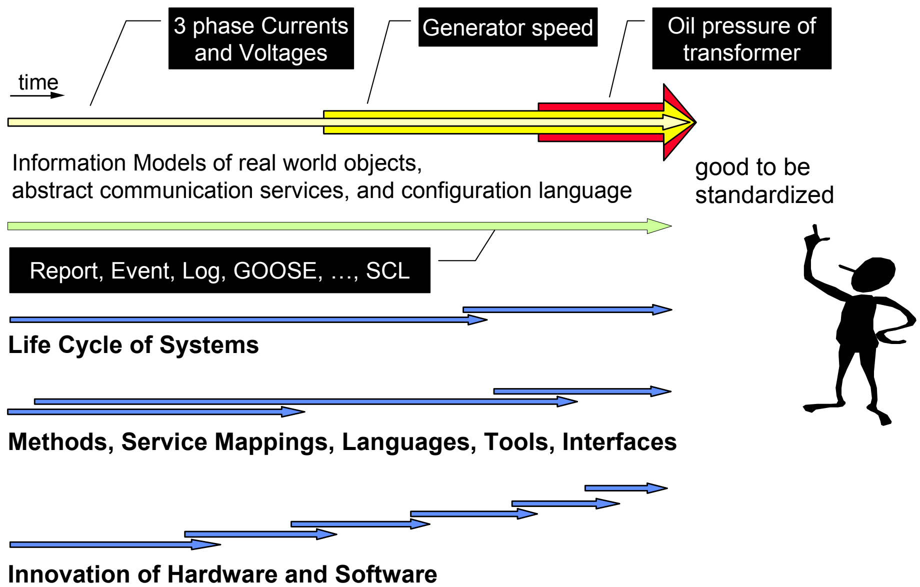

Figure 1: Information models and implementation issues

The models are organized in Logical Nodes containing Data Objects. A Logical Node is for example the "MMXU": The measurements and calculated values of a three phase electrical system. Figure 2 depicts the application of the standard Logical Node "MMXU" for different voltage levels.

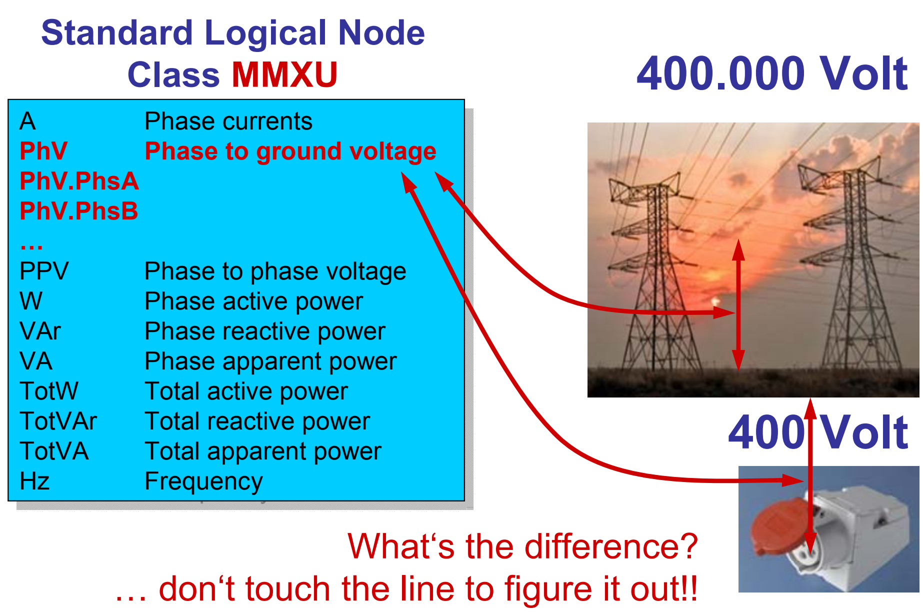

Figure 2: Information model of electrical values

IEC 61850 and related standards define thousands of "signals" as Data Objects organized in Logical Nodes. The list of more 280 standardized Logical Nodes can be found in the Annex.

3 Information models of IEC 61850-7-4 Edition 2

The first Edition of IEC 61850-7-4 "Compatible logical node classes and data classes" contained some 90 Logical Nodes and 500 Data Objects (see Figure 3). They mainly were intended to provide information for control and protection of substation equipment. A few years after the IEC TC 57 WG 10 defined the core document IEC 61850-7-4 Edition 1 several groups started to extend the models for additional application domains. One of the first crucial areas of extensions was the condition monitoring of wind turbines as well as circuit breakers.

Figure 3 shows the current status of the IEC 61850 documents that provide models. The Edition 2 of IEC 61850-7-4 is out for FDIS ballot until February 2010.

150 Logical Nodes (Ed2) – 90 (Ed 1)
800 Data Objects (Ed2) – 500 (Ed 1)

60 Logical Nodes
350 Data Objects

Document	Title	Publication	Edition 2
7-3	Basic communication structure – Common data classes	IS Ed1:2003-05	FDIS 2010-06
7-4	Basic communication structure – Compatible logical node classes and data classes	IS Ed1:2003-05	FDIS 2010-02
7-410	Hydroelectric power plants - Communication for monitoring and control	IS Ed1:2007-08	CD 20xx
7-420	Communications systems for distributed energy resources (DER) - Logical nodes	IS Ed1:2009-03	CD 20xx
7-5	Basic communication structure – Usage of information models for substation automation applications	DC 2010-08	
7-500	Use of logical nodes to model functions of a substation automation system	DC 2010-08	
7-510	Use of logical nodes to model functions of a hydro power plant	DC 2009-12	
7-520	Use of logical nodes to model functions of distributed energy resources	Draft 2010	
7-10	Web-based and structured access to the IEC 61850 information models	DC 2009-12	
		current work in 2009/2010	current work in 2009/2010

updated 2009-12-28

50 Logical Nodes (Draft 2008-05)
450 Data Objects (Draft 2008-05)

Figure 3: Information models in IEC 61850

The second edition specifies more than 150 Logical Nodes. The major technical changes with regard to the first edition are as follows:

- Corrections and clarifications according to information letter;
- Extensions for new logical nodes for the power quality domain;
- Extensions for the model for statistical and historical statistical data;
- Extensions regarding IEC 61850-90-1 (substation-substation communication);
- Extensions for new logical nodes for monitoring functions according to IEC 62271;
- New logical nodes from IEC 61850-7-410 and IEC 61850-7-420 of general interest.

Examples of new Logical Nodes in IEC 61850-7-4 Edition 2 are Logical Nodes for Functionblocks, for Transducers, and Monitoring and Supervision.

Logical Nodes for Functionblocks

The following Logical Nodes expose information used in Functionblock applications:

1. Counter – FCNT
2. Curve shape – FCSD
3. Generic filter – FFIL
4. Control function output limitation – FLIM
5. PID regulator – FPID
6. Ramp function – FRMP
7. Set-point control function – FSPT
8. Action at over threshold – FXOT
9. Action at under threshold – FXUT

An example of a PID loop control with a Logical Node "FPID" representing its attributes (or input and output signals) is shown in Figure 4.

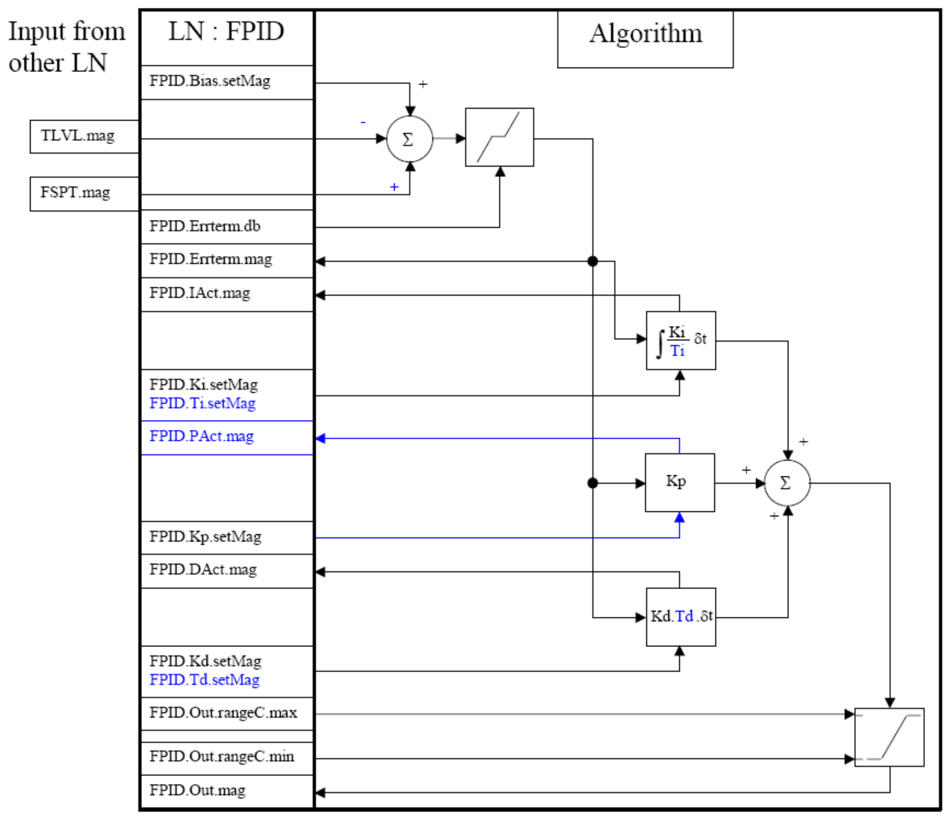

Figure 4: PID Logical Node

Note that IEC 61850 DOES NOT specify the PID loop control algorithm, logig, or function. IEC 61850-7-4 Logical Nodes provide the "interface" or the presentation of the signals, the configuration of the object models and the exchange of the values. The Data Object "KP" (Proportional gain) can be set by an ACSI service. Or the Data Object "DAct" (Derivative action) can be read, reported, logged, or sent by a GOOSE message. All Data Objects can be monitored by using the IEC 61850-7-2 service "Reporting" and "Logging".

Many other new Logical Nodes are included in the second edition of IEC 61850-7-4. There is one crucial area to mention: The new Logical Nodes for sensor (transducer) data. Several of these new and other Logical Nodes have been moved from the Edition 1 of IEC 61850-7-410 (Hydro) to IEC 61850-7-4 Edition 2.

Logical Nodes for Transducers (Sensors)

The following list contains 18 new "T" Logical Nodes for transducers; transducers more or less represent raw values from sensors:

1. Angle – TANG
2. Axial displacement – TAXD
3. Current transformer – TCTR
4. Distance – TDST
5. Liquid flow – TFLW
6. Frequency – TFRQ
7. Generic sensor – TGSN
8. Humidity – THUM
9. Media level – TLVL
10. Magnetic field – TMGF
11. Movement sensor – TMVM
12. Position indicator – TPOS
13. Pressure sensor – TPRS
14. Rotation transmitter – TRTN
15. Sound pressure sensor – TSND
16. Temperature sensor – TTMP
17. Mechanical tension / stress – TTNS
18. Vibration sensor – TVBR
19. Voltage transformer – TVTR
20. Water acidity – TWPH

Most of these Logical Nodes just represent the sampled values from a sensor. The Logical Node for Pressure sensor "TPRS" is shown as an example in Table 1.

Table 1: Logical Node for Pressure sensor

TPRS class			
Data object	**Explanation**		**M/O/C**
LNName	The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22.		
Data objects			
EEHealth	External equipment health		O
EEName	External equipment name plate		O
Measured values			
PresSv	Sampled value of pressure of media [Pa]		C
Settings			
SmpRte	Sampling rate setting		O
Condition C: The data object is mandatory if the data object is transmitted over a communication link and therefore it is visible.			

All "T" Logical Nodes have a Data Object "EEHealth" that provides a simple status information "green", "yellow" or "red" of the real underlying sensor (called ExternalEquipment – EE). They have further a Data Object "EEName" which comprises a huge list of mainly optional information that provides general details about the sensor. The external equipment name plate exposes the following information (without further explanation): vendor, hwRev, swRev, serNum, model, location, name, owner, ePSName, role, primeOper, secondOper, latitude, longitude, altitude, and mrID.

Logical Nodes for Supervision and Monitoring

The Logical Nodes for supervision and monitoring of the Logical Node group "S" comprise also a lot of new models (seven new Logical Nodes):

1. Monitoring and diagnostics for arcs – SARC
2. Circuit breaker supervision – SCBR (new)
3. Insulation medium supervision (gas) – SIMG
4. Insulation medium supervision (liquid) – SIML
5. Tap changer Supervision – SLTC (new)
6. Supervision of Operating Mechanism – SOPM (new)
7. Monitoring and diagnostics for partial discharges – SPDC (new)
8. Power Transformer Supervision – SPTR (new)
9. Circuit Switch Supervision – SSWI (new)
10. Temperature supervision – STMP (new)
11. Vibration supervision – SVBR (new)

The new Logical Node "Circuit breaker supervision – SCBR" (see Table 2) for example comprises a huge number of new Data Objects that represent a more detailed status of circuit breakers than an "EEHealth" Data Object. These Data Objects of have been defined as part of a new Logical Node "SCBR" instead of adding them to the well know Logical Node "XCBR". For a specific real circuit breaker only a subset of the Data Objects may be applicable. Or there may even be a need to define further Data Objects; this can be done easily according the name space concept of IEC 61850-7-1 (which is already defined in Edition 1).

Almost all Data Objects of the "SCBR" are optional. Optional usually means that a vendor of an IEC 61850 compliant device can decide to implement only the mandatory Data Objects – in order to be fast on the market and having a standard conformant device (with the minimum of objects). Very often utility people or system integrators are surprised that a device has just a few objects – they would like to have more. It is up to the utilities to request from the vendors to implement more than just the minimum. This is – of course – completely outside the influence of the standardization groups. The Data Objects of the Logical Node "SCBR" are listed in Table 2. These Data Objects have been discussed by several groups of domain experts of switch gears prior to the inclusion into the Edition 2.

In addition to the features build into the measured value models (common data class "MV"; see also the communication services explained further down) there are some crucial Data Objects like "AbrAlm" (Contact abrasion alarm) and "AbrWrn" (Contact abrasion warning) that define a concrete semantic (meaning) of the object. An alarm may be communicated by a GOOSE message and a software at the subscriber side may act automatically on the receipt of this GOOSE message. The alarm and warning levels are defined in the settings "AbrAlmLev" (Abrasion sum threshold for alarm state) and "AbrWrnLev" (Abrasion sum threshold for warning state). The levels may be configured during device configuration or they may be configured by a communication service (SetDataValues) at runtime.

Table 2: Logical Node "Circuit breaker supervision – SCBR"

Status information	
OpCntRs	Resettable Operation Counter
ColOpn	Open command of trip coil
AbrAlm	Contact abrasion alarm
AbrWrn	Contact abrasion warning
MechHealth	Mechanical behavior alarm
OpTmAlm	Switch operating time exceeded
ColAlm	Coil alarm
OpCntAlm	Number of operations (modeled in the XCBR) has exceeded the alarm level for number of operations
OpCntWrn	Number of operations (modeled in the XCBR) exceeds the warning limit
OpTmWrn	Warning when operation time reaches the warning level
OpTmh	Time since installation or last maintenance in hours
Measured values	
AccAbr	Cumulated abrasion
SwA	Current that was interrupted during last open operation
ActAbr	Abrasion of last open operation
AuxSwTmOpn	Auxiliary switches timing Open
AuxSwTmCls	Auxiliary switches timing Close
RctTmOpn	Reaction time measurement Open
RctTmCls	Reaction time measurement
OpSpdOpn	Operation speed Open
OpSpdCls	Operation speed Close
OpTmOpn	Operation time Open
OpTmCls	Operation time Close
Stk	Contact Stroke
OvStkOpn	Overstroke Open
OvStkCls	Overstroke Close
ColA	Coil current
Tmp	Temperature e.g. inside drive mechanism
Settings	
AbrAlmLev	Abrasion sum threshold for alarm state
AbrWrnLev	Abrasion sum threshold for warning state
OpAlmTmh	Alarm level for operation time in hours
OpWrnTmh	Warning level for operation time in hours
OpAlmNum	Alarm level for number of operations
OpWrnNum	Warning level for number of operations

It is likely that new vendors of IEC 61850 conformant devices will specialize in the domain of condition monitoring and offer more possibilities than traditional vendors. The trend is quite obvious: There are a lot of new solutions for monitoring one or the other part of the process that will hid the road in 2010. The monitoring operation usually does not have a direct link to the automation and protection. It is lees critical than protection functions and devices. Most equipment in the electrical system (mainly at distribution level) is not monitored at all today – operators are quite "blind" on what's going on in distribution networks. With the event of Smart Grids (or Smarter Grids) this is likely to change dramatically.

4 Information models of IEC 61850-7-410 Edition 2 for Monitoring

The Standard IEC 61850-7-410 Edition 1 "Communication networks and systems for power utility automation – Part 7-420: Basic communication structure – Hydropower plant logical nodes" defines some 60 Logical Nodes and 350 Data Objects for various hydropower plant applications.

The Logical Nodes in IEC 61850-7-410 Edition 1, that where not specific to hydropower plants (mainly those that represent transducers, supervision and monitoring information), have been moved to Edition 2 of IEC 61850-7-4 and they will be removed from Edition 2 of IEC 61850-7-410. Most of the modeling examples and background information that was included in IEC-61850-7-410 Edition 1 will be transferred to a technical report TR 61850-7-510.

Edition 2 of IEC 61850-7-410 will include additional general-purpose and supervision and monitoring Logical Nodes, not included in IEC 61850-7-4 (Edition 2), but required in IEC 61850-7-410 in order to represent the complete control and monitoring system of a hydropower plant.

The following Logical Nodes for supervision and monitoring (Group "S") have been specified for Edition 2 of IEC 61850-7-410:

1. Supervision of media flow – SFLW
2. Supervision of media level – SLEV
3. Supervision of the position of a device – SPOS
4. Supervision media pressure – SPRS

Each of these Logical Nodes comprises measured values, status information and settings.

Details are still under discussion in IEC TC 57 WG 18 which is responsible for the Edition 2 of IEC 61850-7-410.

5 Information models of IEC 61850-7-420 Edition 1 for Monitoring

The Standard IEC 61850-7-420 Edition 1 "Communication networks and systems for power utility automation – Part 7-420: Basic communication structure – Distributed energy resources logical nodes" defines some 50 Logical Nodes and 450 Data Objects for various DER domains.

Most Logical Nodes have some status information and measurements that can be used for monitoring. They are usually not defined in separate "S" Logical Nodes.

IEC 61850-7-420 defines the following specific Logical Nodes that are intended to provide special measurements for monitoring various physical processes:

1. Temperature measurements – STMP
2. Pressure measurements – MPRS
3. Heat measurement – MHET
4. Flow measurement – MFLW
5. Vibration conditions – SVBR

The details of the Logical Nodes could be found in IEC 61850-7-420. One example is shown in the following example.

The crucial Data Objects of the Logical Node "MFLW" (Flow measurement) are listed in Table 3. These models are more comprehensive than those that will be defined in IEC 61850-7-4 Edition 2; they may be used for any other application domain as well.

One of the crucial benefits of IEC 61850 is this: Which Data Object is ever missing in any Logical Node, it could be defined as an extension. IEC 61850-7-1 defines the rules for defining new Logical Nodes, new Data Objects or even new common data classes. The concept is called the "name space concept".

Table 3: Logical Node "Flow measurement – MFLW"

Measured values	
FlwRte	Volume flow rate
FanSpd	Fan or other fluid driver speed
FlwHorDir	Flow horizontal direction
FlwVerDir	Flow vertical direction
MatDen	Material density
MatCndv	Material thermal conductivity
MatLev	Material level as percent of full
FlwVlvPct	Flow valve opening percent
Controls	
FlwVlvCtr	Set flow valve opening percent
FanSpdSet	Set fan (or other fluid driver) speed
Metered values	
MtrVol	Metered volume of fluid since last reset

6 Information models of IEC 61400-25 for Monitoring

Some Data Objects are already defined in the current published standard IEC 61400-25-2 "Communications for monitoring and control of wind power plants – Information models". The Logical Node Wind turbine transmission information (WTRM) comprises the Data Objects that represent wind turbine (mechanical) transmission information. The data represent usual transmission topology, consisting of a slow speed shaft, multistage gearbox, a fast shaft and a (hydraulically driven) mechanical brake. In case of a divergent transmission topology (e.g. direct drive, single stage gearbox) or different mounted equipment (e.g. sensors, electromechanical brake), users are free to adapt or extend the data classes. Table 4 shows the Logical Node "WTRM" of the standard IEC 61400-25-2 published in January 2007. Most of the Data Objects of this Logical Node provide monitoring information of the transmission system.

Table 4**:** Logical Node "WTRM"

Data object	Description
Status information	
BrkOpMod	Status of shaft brake
LuSt	Status of gearbox lubrication system.
FtrSt	Status of filtration system
ClSt	Status of transmission cooling system
HtSt	Status of heating system
OilLevSt	Status of oil level in gearbox sump
OfFltSt	Status of offline filter
InlFltSt	Status of inline filter
Measured values	
TrmTmpShfBrg1	Measured temperature of shaft bearing 1
TrmTmpShfBrg2	Measured temperature of shaft bearing 2
TrmTmpGbxOil	Measured temperature of gearbox oil
TrmTmpShfBrk	Measured temperature of shaft brake (surface)
VibGbx1	Measured gearbox vibration of gearbox 1
VibGbx2	Measured gearbox vibration of gearbox 2
GsLev	Grease level for lubrication of main shaft bearing

GbxOilLev	Oil level in gearbox sump
GbxOilPres	Gear oil pressure
BrkHyPres	Hydraulic pressure for shaft brake
OfFlt	Offline filter contamination
InlFlt	Inline filter contamination

Several other Logical Nodes offer Data Objects that can be used for monitoring purposes.

The standard IEC 61400-25-6 "Communications for monitoring and control of wind power plants – Logical node classes and data classes for condition monitoring" is intended to provide more sophisticated Data Objects that can be used for higher level diagnosis.

IEC 61400-25 defines information models and information exchange models for monitoring and control of wind power plants. The modeling approach (for information models and information exchange models) of IEC 61400-25-2 and IEC 61400-25-3 uses abstract definitions of classes and services such that the specifications are independent of specific communication protocol stacks, implementations, and operating systems. The mappings of these abstract definitions to specific communication profiles are defined in IEC 61400-25-4 (see **Figure 5**). The definitions in parts IEC 61400-25-1 to IEC 61400-25-5 apply also for part 6.

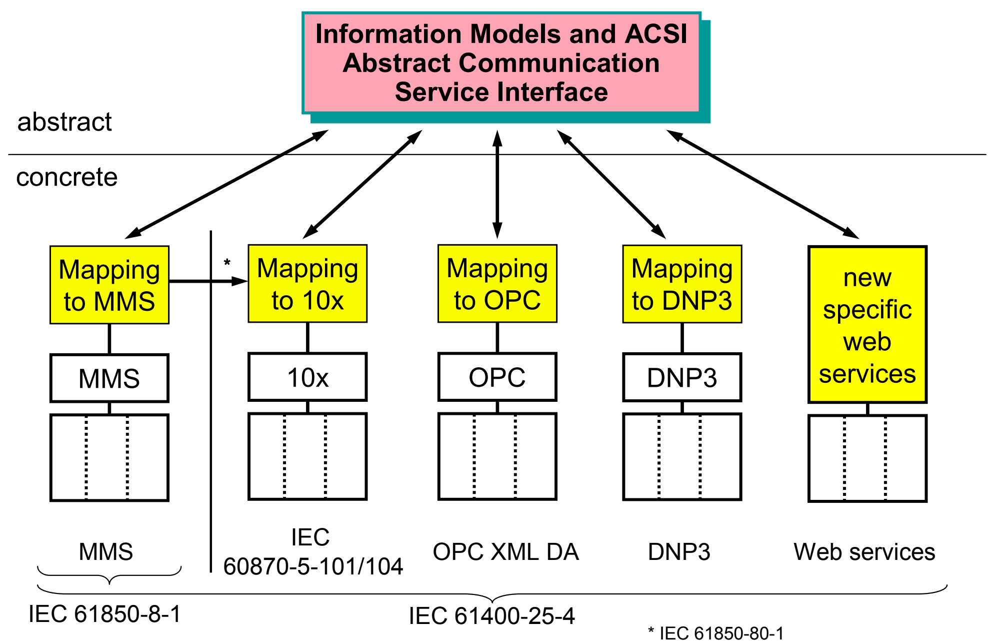

Figure 5: The mappings of IEC 61400-25-4

The purpose of part 6 is to define an information model for more specialized condition monitoring information and to define how to use the existing definitions of part IEC 61400-25-2 and to define the required extensions in order to describe and exchange information related to condition monitoring of wind turbines. The models of condition monitoring information defined in this standard may represent information provided by sensors or by calculation.

In the context of this standard condition monitoring means a process with the purpose of observing components or structures of a wind turbine or wind power plant for a period of time in order to evaluate the state of the components or structures and any changes to it, to detect early indications of impending failure.

Condition monitoring is most frequently used as a Predictive or Condition-Based Maintenance technique (CBM). However, there are other predictive maintenance techniques that can also be used, including the use of the Human Senses (look, listen, feel, smell) or Machine Performance Monitoring techniques. These could be considered to be part of the condition monitoring.

Condition monitoring techniques that generate information to be modeled include, but are not limited to techniques such as:

- Vibration measurements and analysis,
- Oil debris analysis,
- Temperature measurement, and
- Strain gauge measurement.

Components and structures can be monitored by using automatic instrumentation as well as using a manual process.

The condition monitoring functions may be located in different physical devices. Some information may be located in a turbine controller device (TCD) while other information may be located in an additional condition monitoring device (CMD). Various actors may request to ex-change data located in the TCD or CMD. A SCADA device may request the information from a TCD or CMD; a CMD may request information from a TCD and vice versa. The information exchange between any two devices requires the use of information exchange services defined in IEC 61400-25-3 or added in part 6.

The use case of having the condition monitoring functions located in the turbine controller device is a special use case. That use case does not require information exchange services for the information exchange between the condition monitoring functions and the turbine controller functions. The case of having separate devices is the more comprehensive use case. This is used as the typical topology in this part of the standard. The special case of both functions in one device could be derived from the most general use case.

It may also be required to build a hierarchical model of automatic turbine controller and condition monitoring devices/functions. A simple condition monitoring device (CMD; providing measured values and status information and very basic monitoring capabilities). This CMD may retrieve information from the underlying CMD or TCD and may further process and analyze the measured values and status information.

In condition monitoring systems predefined triggers are applied to initiate a sequence of events, for example issuing an alarm to the local SCADA system or sending a message to a monitoring centre in order to prevent further damage on components or structures. In general such messages can be used by a Condition Monitoring Supervision function to generate actionable information which can be used by a service organization to create work orders and initiate actions. Figure 6 illustrates the information chain of a system using condition monitoring to perform condition based maintenance.

Figure 6 illustrates how data are refined and concentrated through the information chain, ending up with the ultimate goal of condition based maintenance – actions to be performed via issuing work orders to maintenance teams.

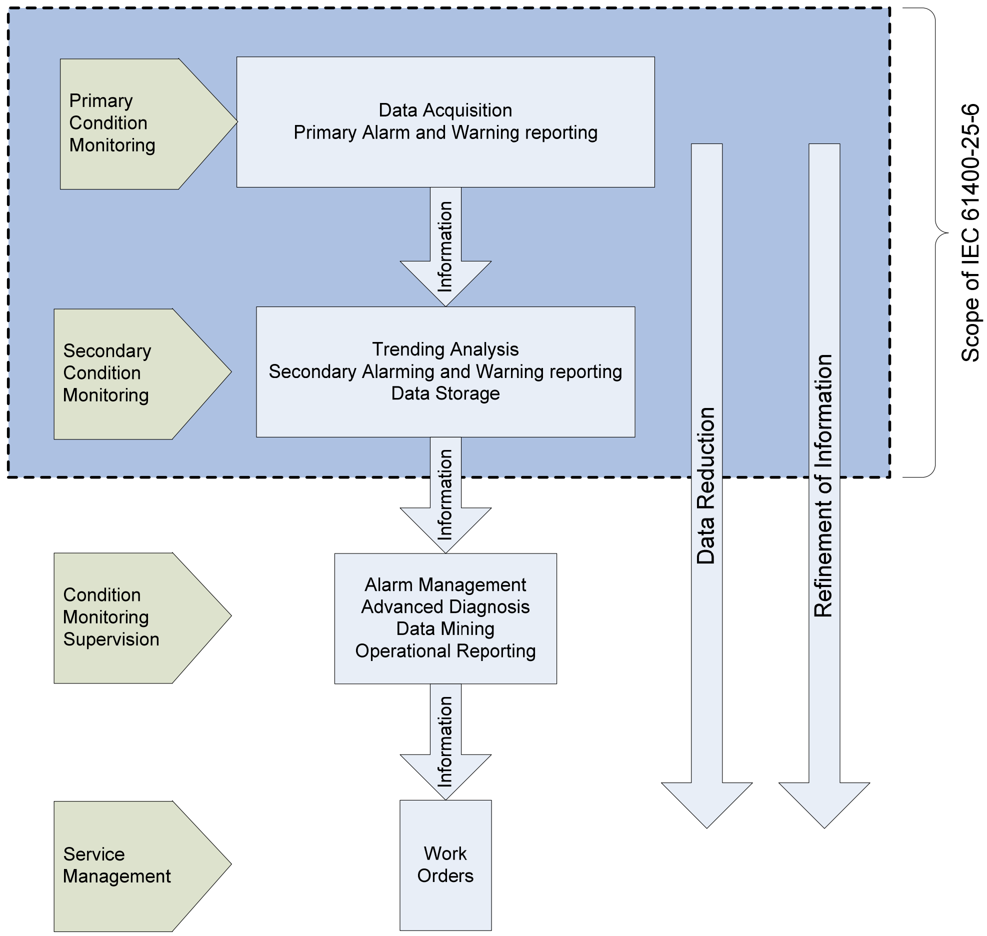

Figure 6: The information chain of condition based maintenance

Figure 6 shows the scope of IEC 61400-25-6 and the typical information chain of condition monitoring systems. The local (primary) part of the chain could be named as condition monitoring localized in the wind turbine and the wind farm SCADA system, but the local functionality can vary from system to system. The centralized (secondary) data retrieval performed by for example a control centre system is often named as a back-office system. The decreasing sizes of the boxes illustrate the data reduction and the transformation of data into more useful information with an enhanced value.

The FDIS (Final Draft International Standard) of part IEC 61400-25-6 is expected to be available in early 2010.

7 Communication services for monitoring

The part IEC 61850-7-2 (ACSI – Abstract communication service interface) and IEC 61400-25-3 define the basics for information models and services and part IEC 61850-7-4 and IEC 61400-25-2 (Logical Nodes and Data Objects) defines concrete information models (the Data Objects that represent the values to be monitored). It is crucial to understand that the standards IEC 61850 and IEC 61400-25 do not define new process data – the standards assign useful names and types to real-world data. These names are valid internationally.

The ACSI provides the following basic definitions we need for monitoring:

- Logical Nodes are used as containers of any information (Data Objects) to be monitored,
- Data Objects are used to designate useful information to be monitored,
- Retrieval (polling) of the values of Data Objects (GetDataObjectValues),
- Send events from a server device to a client (spontaneous Reporting),
- Store historical values of Data Objects (logging),
- Exchange sampled values (current, voltages and vibration values),
- Exchange simple status information (GOOSE), and
- Recording functions with COMTRADE files as output.

These basic definitions are explained in the following with regard to the use case "monitoring".

Logical Nodes

Many Logical Nodes are explicitly defined to represent a list of Data Objects that relate to measurements like temperature, pressure, level, gas density, etc. Many other logical nodes are a mix of controllable Data Objects, objects for settings, protection, and so on.

An example of a Logical Node comprising only monitoring information is the Logical Node "Circuit breaker wear supervision" (SCBR) of the draft edition 2 of IEC 61850-7-4 is shown in Table 5 (this and the following Logical Node tables are just showing an excerpt of Data Objects).

Table 5**:** Circuit breaker wear supervision Logical Node (SCBR)

Data object	**Description**
Status information	
Col1Opn	Open command of trip coil 1
Col2Opn	Open command of trip coil 2 (usually as backup protection coil)
AbrAlm	Contact abrasion alarm
AbrWrn	Contact abrasion warning
Measured values	
AccAbr	Cumulated abrasion coefficients
TripA	Current that was interrupted during last open operation
ActAbrCoef	Abrasion coefficient of last open operation
Settings	
AbrAlmLev	Abrasion coefficient sum threshold for alarm state
AbrWrnLev	Abrasion coefficient sum threshold for warning state

Operating a breaker and especially tripping a short circuit causes always some abrasion (or erosion) of the breaker contacts. The supervision relates to a single phase since each phase has its own contact.

The first seven Data Objects can be used for monitoring purposes; the last two are used for settings limits. The communication services applicable are explained below.

Data Objects

There are several categories of Data Objects that provide various aspects of the monitoring process:

- Status information (single or double point information),
- Measured information (analogue values measured or calculated, and
- Settings (set ratings or limits for monitoring)

The standards related to IEC 61850 define hundreds of Data Objects of these categories.

Some basic aspects with regard to monitoring are explained in the following paragraphs:

Status information: In most cases there is a need to provide several details of the status. IEC 61850-7-3 provides these attributes by, e.g., the common data class SPS (single point status as defined in IEC 61850-7-3):

- stVal BOOLEAN TrgOp=dchg
- q Quality TrgOp=qchg
- t TimeStamp

Any change of the value of the status with the standard name "stVal" can be used to trigger a report (comprising the values for stVal, q and t) to be sent to clients or to trigger to log the values of stVal, q and t to one or multiple logs. It is also possible that a client reads these values (stVal, q and t) at any time to get the values of the last change or the current value.

These values may also be used to be sent as content of a GOOSE messages. GOOSE messages are sent by multicast to any IEDs (Intelligent Electronic Device) connected to the same subnetwork. Even a sampled value message may sent the values (stVal, q and t) continuously with the same rate (e.g. 4 kHz) as the current and voltage samples from CTs and VTs.

Independent of the use of reporting, logging, GOOSE, or sampled value exchange, the data to be exchanged has to be specified by a DataSet. A DataSet contains a list of references to Data Objects and parts of it (the so-called functionally constraint data, FCD, or data attributes, FCDA).

A DataSet may comprise several status information and a few measurements for example.

Measured values: IEC 61850-7-3 provides attributes for measured values. The most common class is the common data class MV (measured value) with the following attributes:

- instMag AnalogueValue
- mag AnalogueValue TrgOp=dchg
- range ENUMERATED TrgOp=dchg
- q Quality TrgOp=qchg
- t TimeStamp
- units Unit
- db INT32U
- zeroDb INT32U
- sVC ScaledValueConfig
- rangeC RangeConfig

Any change of the magnitude value (with the standard name "mag") can be used to trigger a report (of mag, range, q and t) to be sent to clients or to trigger to log these values to one or multiple logs. It is also possible that a client reads these values at any time to get the last change. The values may also be used for other services like GOOSE.

The use of mag (a deadband or filtered value) and range in conjunction with reporting and logging is explained below.

The attribute units, db, sVC and rangeC are used to configure the engineering unit (e.g., V for Volt), the multiplier (M for Mega), the deadband value for filtering the analogue value, the scale factor and offset (for integer values) and the range configuration. Those attributes that have a impact on the monitoring of measured value are explained below.

Statistical and historical statistical information

Measurement Data Objects usually (in Edition 1) refer to RMS (root mean square) values or just current values, provided at the time when they have been measured. In many applications there is a need to refer also to statistical values of a measurement, e.g., maximum value of an hour or

15 minutes interval. The statistical values require some minor extensions of the first edition of IEC 61850-7-x. The standard IEC 61400-25-2 has already published the solution for statistical data.

In many application domains such as wind power plants, it is required to provide additional information of a basic analogue value:

- **Statistical information** (for example, minimum value calculated for a specified time period, for example, minimum value of last 1 hour)
- **Historical statistical information** (for example, log of minimum values of the sequence of values calculated above, for example, last 24 hourly values)

This additional information may be derived from the basic analogue values. It may be the only information provided – depending on the application requirements.

The models for the statistical and historical statistical data are explained conceptually in Figure 7.

On the left hand side are the basic data representing the cur-rent values (PRES), i.e. some instantaneous analogue (or integer) values that are contained in the logical node instance XXYZ.

The upper half depicts the method defined for statistical values. The first example is the instance XXYZ1 of the logical node class XXYZ. The analogue values represent the calcu-lated maximum values derived from the instance XXYZ. The logical node XXYZ1 has special setting data that indicate that the values are maximum values and that the calculation method is "periodic". The period starts after a start command or by local means. At the end of the period the calculated maximum values of the instance XXYZ1 are overwritten by the new values.

The maximum values can be used to calculate the minimum maximum values in – of course – a much longer period than for the maximum calculation in XXYZ1. The instance XXYZ2 may represent the minimum value of the max value of the last 10 days.

Setting parameters other than PERIOD may be used to specify calculation modes. A calculation mode set to TOTAL means that the calculated maximum values are calculated since the first start of the device or of the involved application. A calculation mode set to SLIDING means that the calculated maximum values are calculated over a sliding window whose width can be set by means of a special interval type setting (e.g. hour, day, week).

The lower part of the figure shows the conceptual model of the historical statistical data. In this model the calculated val-ues (in this case the maximum values with calculation mode set to PERIOD) are stored in sequence in a log. The calcula-tion in the example starts at midnight of 2004-10-03. The in-terval is 1 h. After that first hour the first log entry is written. After the second hour the second entry contains the value of the second hour. After five (5) hours the log contains the values of the last three hours (intervals 02-03, 03-04, 04-05).

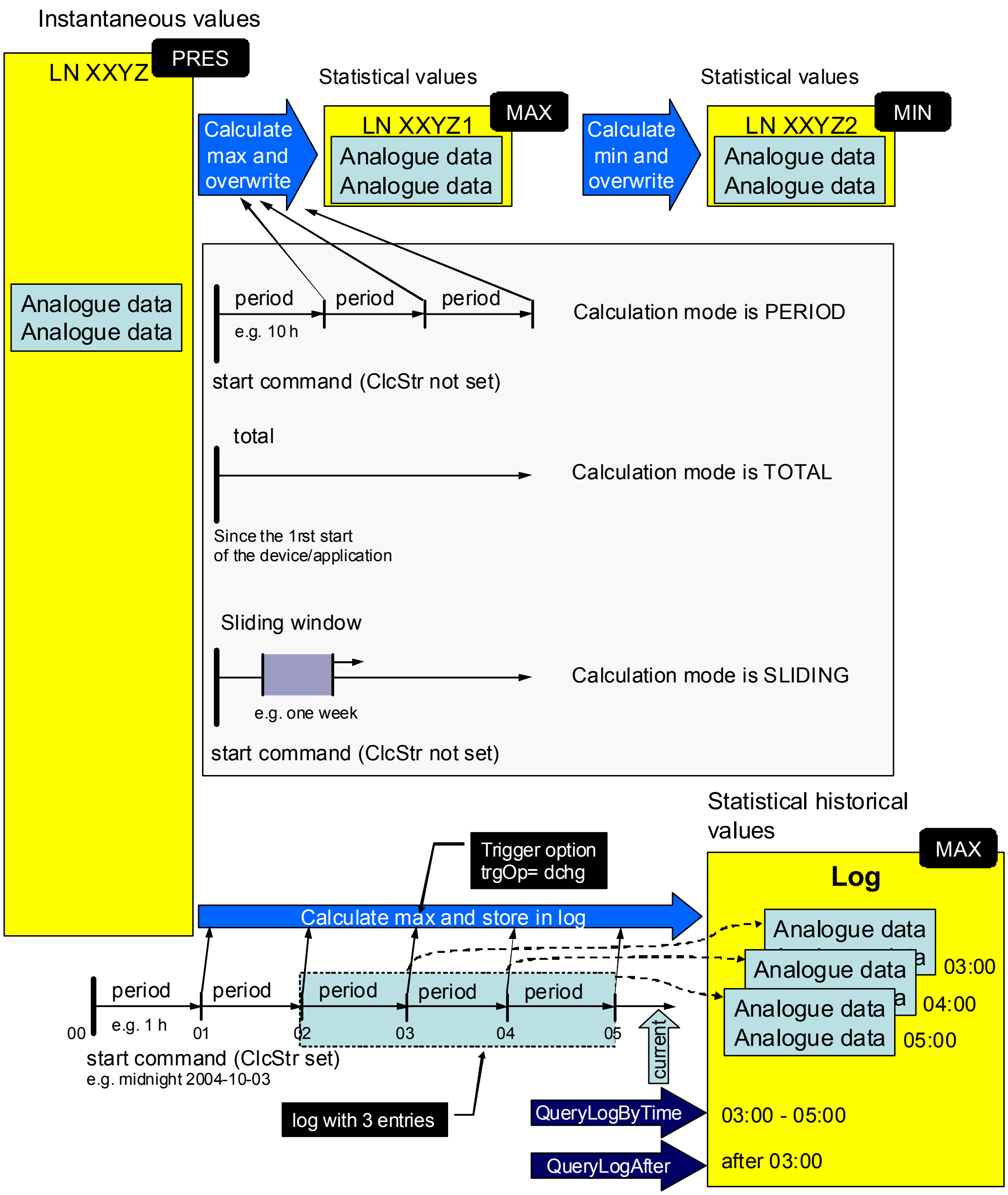

Figure 7: Statistical and Historical Statistical Data Objects (1)

The statistical data model is based on the calculation of analogue values contained in other logi-cal nodes. The top logical node LN XXYZ in Figure 2 refers to three technologi-cal logical nodes of the same Type (for example MMXU). The top logical node (LN XXYZ) represents the instanta-neous measured values. The second and third logical nodes are the statistical logical nodes, i.e., the logical nodes that represent the calculated values (LN XXYZ1 represents the MIN values, the LN XXYZ2 the MAX values).

The two logical nodes on the left of the bottom in Figure 2 (XXYZ1 and XXYZ2) represent mini-mum (MIN) and maxi-mum (MAX) values of the analogue data represented in the top logical node (XXYZ). The two logical nodes make use of the setting data ClcSrc (calculation source). The common data class of ClcSrc is ORG, "object reference setting group" and is used to reference the source logical node for the calculation. For both logical nodes, ClcSrc has the value XXYZ. Each logical node with analogue data can be used as a source. Addi-tionally, they have the data ClcStr (calculation start) and ClcExp (calculation expired) and the setting data ClcPerms (calculation period), ClcSrc (calculation source), and ClcMod (calculation mode).

With the settings ClcMod, ClcMthd, ClcPer and ClcSrc, the behavior of the logical node can be controlled. For periodic calculation, the "event" ClcExp set to TRUE can be used as an event to report the new value (the statistical value) by the re-port control block or it may be logged as historical statistical data for later retrieval.

The data names of the "Data" in all logical nodes shown **Figure 8** are the same, i.e., in all three logical nodes. The data are contained in different logical node instances (XXYZ, XXYZ1, and XXYZ2). These result in the following refer-ences: XXYZ.Data1, XXYZ1.Data1, and XXYZ2.Data1.

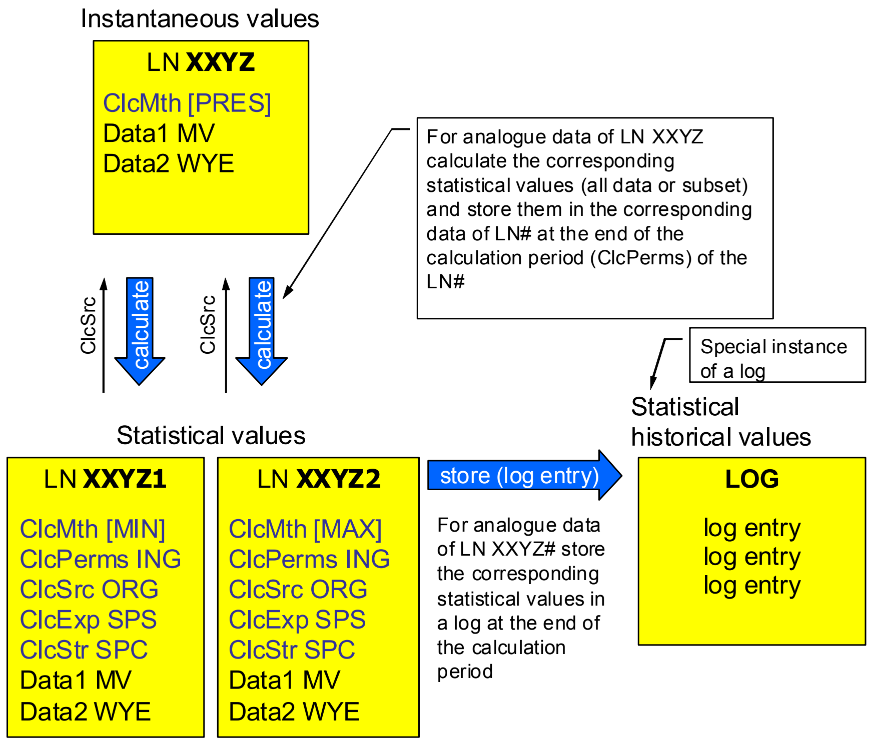

Figure 8: Statistical and Historical Statistical Data Objects (2)

Settings: Setting Data Objects are used to set specific val-ues for limits and other purposes. The purpose is usually de-fined with the semantic of a Data Object.

In the example of the Logical Node SCBR the two settings are used to monitor when to change status values of the warn-ing AbrWrn and the alarm Data Object AbrAlm. These Data Objects are single point status objects that can be used by the various communication services.

Retrieve (poll) the values of Data Objects

Any Data Object, any part of it and any group of them (optionally through a DataSet) can be read from a client. The corresponding services are GetDataValues and GetDataSetValues.

A DataSet may be defined by the service CreateDataSet (online), during configuration, or it may be built in.

Send events from a server device to a client (spontaneous Reporting)

Reporting is one of the most powerful service models in IEC 61850. It allows to configure the reporting behavior of the server device in a wide range of possibilities.

The basic concept of reporting is that values to be reported are specified by a DataSet object. The DataSet is a list of references to the objects to be reported; each referenced object is called a member of the DataSet. If a change of a value of one of the members happens the server creates a report message and sends the new value to the corresponding client. The change is also called a trigger – to trigger sending a report.

The trigger options are defined in the Data Objects (in Logical Nodes). There are, for example, two trigger options (data value change and quality value change) defined for each status Data Object derived from the common data class SPS:

SPS (single point status):

– stVal	BOOLEAN	TrgOp=dchg
– q	Quality	TrgOp=qchg
– t	TimeStamp	

The two Data Objects of the Logical Node SCBR (from above) are derived from the common data class SPS:

"AbrAlm" – Contact abrasion alarm and "AbrWrn" – Contact abrasion warning

If the cumulated abrasion coefficients "AccAbr" has reached the value of the "AbrWrnLev" (as configured by "AbrWrnLev" -abrasion coefficient sum threshold for warning state) the value of "AbrWrn" changes and can be reported if the object is a member of the corresponding DataSet.

Setting Data Objects are used to set specific values for limits and other purposes. The purpose is usually defined with the semantic of a Data Object.

In the example of the Logical Node "SCBR" the two settings are used to monitor when to change status values of the warning "AbrWrn" and the alarm Data Object "AbrAlm". These Data Objects are single point status objects that can be used by the various communication services.

The example has shown that any analog value (measurement or calculated value) can be monitored for limit violations. This approach of defining Data Objects for the analogue value "AccAbr", the limit configurations "AbrWrnLev" and "AbrAlm-Lev" and the warning "AbrWrn" and alarm "AbrAlm" is quite often used in the Logical Nodes in edition 2 of IEC 61850-7-4 and in other documents.

The measured value common data class "MV" contains already some mechanisms to monitor analogue values.

IEC 61850-7-3's common data class MV (measured value) has the following values with regard to reporting:

– mag	AnalogueValue	TrgOp=dchg
– range	ENUMERATED	TrgOp=dchg
– q	Quality	TrgOp=qchg
– t	TimeStamp	
– db	INT32U	
– rangeC	RangeConfig	

The use of the attributes mag and range are shown in Figure 9 and Figure 10.

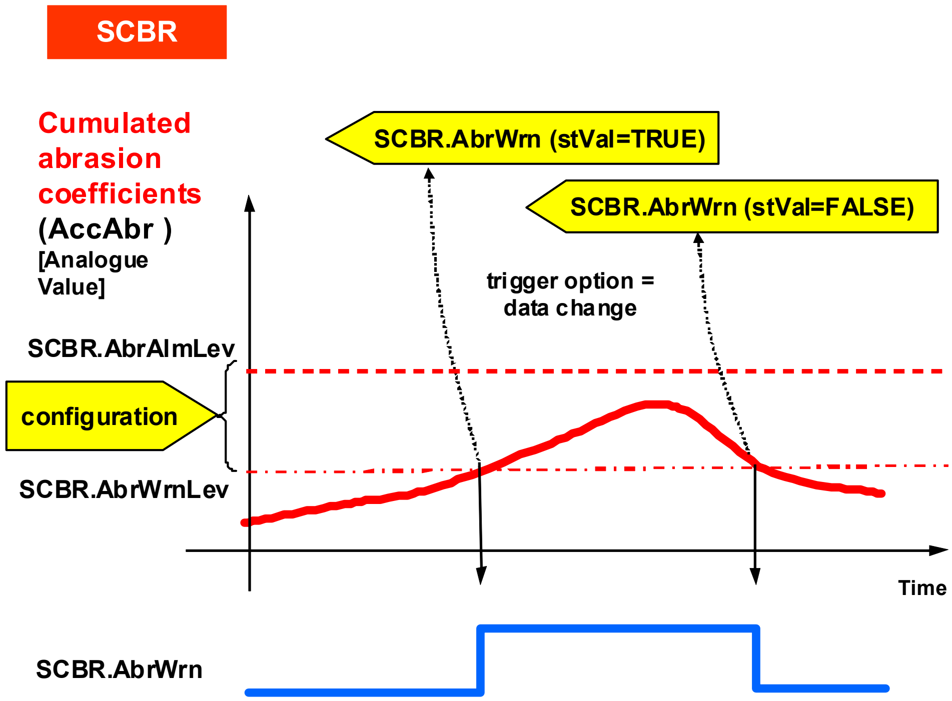

Figure 9**:** Deadband Filtering and Reporting (logging)

The analog value "AccAbr" is monitored for relative changes configured by "db" (deadband configuration). The deadband configuration specifies a relative change in per cent of the whole value range: Min to Max. In our case the value is 10 per cent. Any change of the value by +/10 per cent issues a trigger that can be used to report or log the new value.

The deadband configuration value can be configured during engineering, IED configuration, or online with the SetData-Value service. The smaller the value the more reports may be generated. It is up to the system integrator or operator (later on) to make sure that the whole system is configured in a way that not too many reports are generated. If for thousands of Data Objects the configuration parameter db is very small and the change rate of the values is high then it could happen that the IEDs and the network are flooded. Be aware everything is limited!

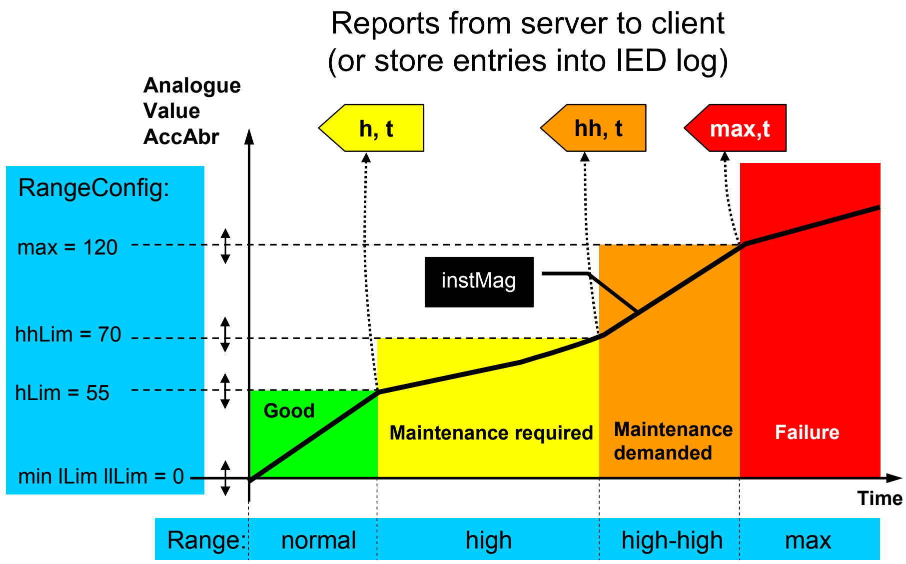

Figure 10**:** Range monitoring and reporting (logging)

The range monitoring uses the limits specified by the range configuration values for min, llLim, lLim, hLim, hhLim and max. Each time the analog value AccAbr crosses one of these limits a trigger is issued. The triggers can be used to report the analog value with the range value min, low-low, low, normal, high, high-high, and max. In addition to these two values the quality information q and timestamp t can be communicated with the report. Instead or in addition to the report the values may be placed into a log.

The meaning of the range values can de defined by the application. In the example it is defined as good, maintenance required, maintenance demanded, and failure. This approach (which is build-in in each analog value derived from the common data class "MV") is different to the approach discussed earlier with the warning and alarm Data Objects and the configuration of the two limits as Data Objects. There is one difference: the Data Objects "AbrAlm" (Contact abrasion alarm) and "AbrWrn" (Contact abrasion warning) represent already a semantic. The two Data Objects can easily be used for GOOSE messaging to trigger an automatic function, e.g. to block operation or to control something in the substation.

A comprehensive modeling approach for monitoring of analog values is expected to be written by IEC TC 57 WG 10. This could be used for modeling monitoring of analog values in future applications. It is the freedom of the modelers to model the monitoring function one way or the other. All possibilities defined in the various standards today are conformant to IEC 61850 in general.

Store historical values of Data Objects (logging)

The logging of values of members of a DataSet is exactly the same as the reporting – except that the values are stored in a local buffer (the log – a circular buffer) and that clients have to initiate queries to retrieve logged data values.

The query log service is simple and straight forward: A client specifies the log to be queried, a starting time and ending time, a start time, or an ending time. In the first case all values stored between the two times are transmitted, in the second case all values after the start time are provided and in the third case all values before the ending time will be sent to the client.

For different applications it is recommended to think about how to best configure the logging: one log or multiple logs. A DataSet which causes frequent changes that may be logged for a short period (e.g., one day) may use a separate log. Because other Data Objects (not frequently changing) in another DataSet may have to be logged for a year or more. Putting these two streams in one log would cause the low frequent values being overwritten by the high speed values.

Be aware that reporting and especially logging is now migrating from control center SCADA systems down to the IED level. The functions reporting and logging are providing are well known – but usually implemented in SCADA systems; often on top of RTUs (remote terminal units).

Exchange of sampled values (SV)

The sampled value exchange mechanism has been defined in IEC 61850-7-2 and IEC 61850-9-2 for replacing the many wires carrying analog signals of voltage and current measurements. The samples to be transmitted are defined by a DataSet. A DataSet may contain analog and any other type of data, e.g., status values.

For the use of sampled value exchange in so-called Merging Units (MU) the UCA IUG (UCA International Users Group) has defined an implementation guide "9-2LE". This guide provides a set of concrete settings for the DataSet and the control block. The DataSet comprises a fixed set of four currents and four voltages. Two sampling rates are defined: 80 samples/period for protection and 256 samples/period for metering. First Merging Units are available.

The sampled value exchange method can also be used for the high speed transmission of vibration data. Think of a huge hydro power plant with some 50 generators. Each and every set of generator and turbine has a lot of sensors that monitor the turbine, generator, and other components. There is now way to continuously record all samples of vibration sensors. The vibration sensor cold trigger a report sent to the maintenance department indicating a warning level. The maintenance people can now start a sampled value control block to send high speed samples from the field up to the office. At the subscriber of the sample stream there could be a analyzing tool that does some online analysis of the sample stream as it arrives. After some time of analysis the publisher may be disabled sending a high frequency stream of samples.

Exchange simple status information (GOOSE)

GOOSE (Generic Object Oriented Substation Event) is used to reliably distribute events very fast in the whole substation (subnetwork). The values to be sent are also specified by a DataSet. The DataSet members may be status information or any other values. After a change of any member of the DataSet the GOOSE message is sent immediately and repeated in a very high frequency. After several repetitions the frequency turns down to a low value (may be every 100 ms). Every 100 ms the receiver (subscriber) can expect new GOOSE message.

If the subscriber does no receive the message after 100 ms, it can expect that the sender (publisher) or the communication network have a serious problem. With that mechanism it is possible to monitor the publisher and communication system continuously. This is not possible in today's wire based exchange of status information.

Recording functions with COMTRADE files as output

The recording functions are defined in IEC 61850-7-4 by a set of Logical Nodes included in the group R – protection related Logical Nodes. They are used to model typical (and well known) recording functions in different devices that have (already!) recording capabilities. The recording mechanisms are NOT defined in IEC 61850.

RDRE is a Logical Node representing the acquisition functions for voltage and current wave forms from the sensors (CTs and VTs), and for position sensors (usually binary inputs). Calculated values such as frequency, power and calculated binary signals can also be recorded. "RDRE" is used also to define the trigger mode, pre-trigger time, post-trigger time, pre-fault, post-fault, etc. attributes of a disturbance-recording function.

The Logical Node "RADR" is used to represent a single analog channel, while "RBDR" is used for the binary channels. Thus the disturbance recording function is modeled as a logical device with as many instances of "RADR" and "RBDR" Logical Nodes as there are analog and binary channels of the real recorder function available.

8 RWE R&D Process Bus Project

The IEC Standard 61850 is usually used for station and bay level communication. The standard comprises also a digital communication with the process level. This allows to integrate primary substation equipment, in particular electronic instrument transformers in a standardized way into the digital communication of the substation automation system (SAS).

RWE (second biggest German utility) has launched a multi-vendor project with the objective of collecting experience with this new process bus technology in a real 380/110 kV substation environment. An already existing 380/110 kV power transformer and its related bays were equipped with the new process bus technology in parallel to the existing active SAS. Two non-conventional CTs and VTs have been added to the primary equipment. The digital interface of an instrument transformer is the so called "merging unit". Samples from conventional instrument transformers using the 100V/1A interface can also communicate using a merging unit as a sample value publisher. Thus a merging unit operates as a decentralized A/D-converter.

The communication network consists of two fully redundant ring busses. Several devices are connected: merging units, protection devices, bay controllers, electronic circuit breaker devices, a voltage controller, a tap changer controller, power transformer monitoring, an HMI and the gateway to the existing SAS.

The topology is based on the so-called "9-2LE" (light edition) published by the UCA users group based on IEC 61850-9-2 Edition 1. According to the specification the data volume per merging unit is about 5 MBit/s for 50 Hz and about 6 MBit/s for 60 Hz comprising one set of 3-phase current and voltage samples. Other time critical data (e.g. GOOSE messages) and also non time critical data (e.g. file transfer) could be transmitted over the same architecture. Figure 11 shows the topology of the process bus and the substation.

One of the key requirements was the implementation of a transformer monitoring system based on appropriate Logical Nodes and Data Objects as well as a selection of crucial client-server communication services. Additional monitoring information is provided by circuit breaker IEDs.

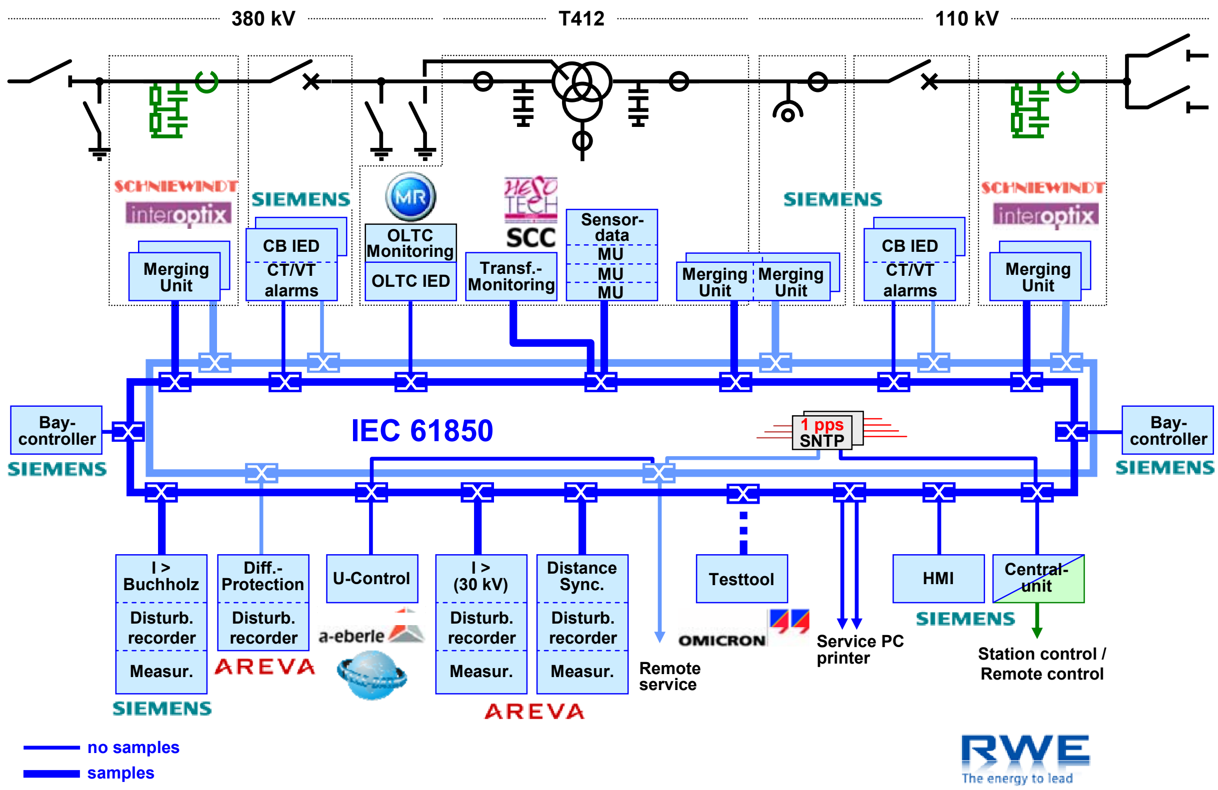

Figure 11: Topology of RWE Process Bus project

The Transformer and the load tap changer are monitored by two separate monitoring systems providing each an IEC 61850 server with the appropriate list of Logical Nodes and Data Objects. The transformer monitoring information models are listed in Table 6.

Table 6: Logical Nodes for Transformer Monitoring

LN	Data Object
MMXU1	Measurements 380 kV
MMXU2	Measurements 110 kV
MMXU3	Measurements 30 kV
YPTR1	Transformer
SIML1	Insulation measurement Transformer
SIML2	Insulation measurement circuit breaker
CCGR1	Transformer cooling group 1
CCGR2	Transformer cooling group 2
CCGR3	Transformer cooling group 3
CCGR4	Transformer cooling group 4
CALH1	Summary alarm
ZAXN1	Monitoring 3 phases of cooling group 1

ZAXN2	Monitoring 3 phases of cooling group 2
ZAXN3	Monitoring of cooling group 1
ZAXN4	Monitoring of cooling group 2

The process bus interface to the primary equipment provides all crucial information about their status. The key benefit is that all the information from the process level is communicated in a standardized way. Proprietary communication links – using may vendor specific solutions – are replaced by a single solution supported by multiple vendors.

The communication services can be used to retrieve the crucial status information of the primary equipment.

The transformer monitoring system comprises the information models shown in Figure 12 and Figure 13.

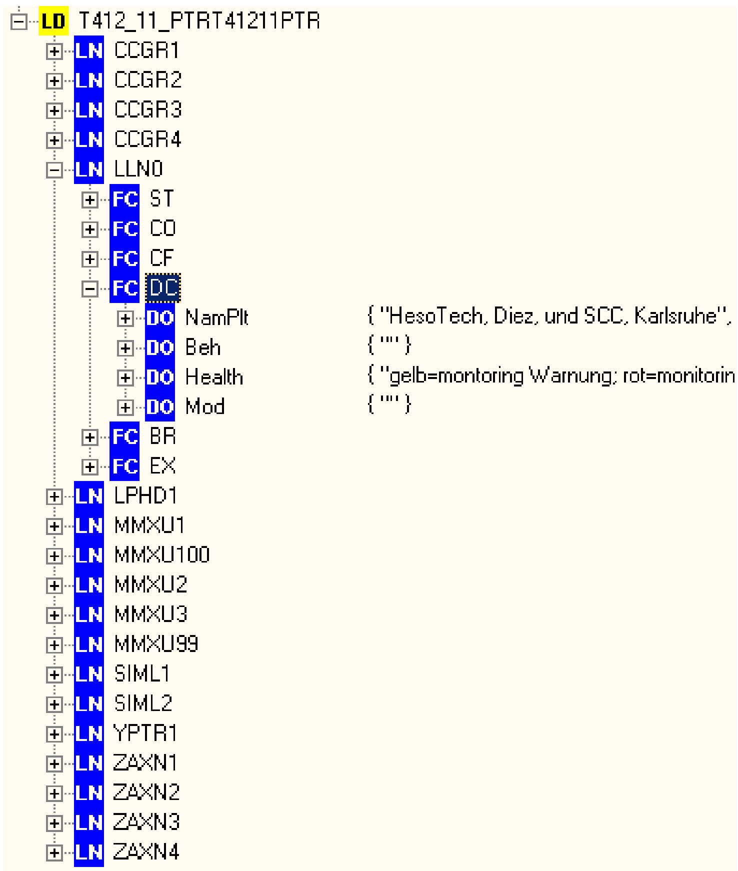

Figure 12**:** Transformer monitoring model for RWE R&D project (1)

Details, e.g., implemented in the SIML1 Logical Node are depicted in Figure 14.

Figure 13**:** Transformer monitoring model for RWE R&D project (2)

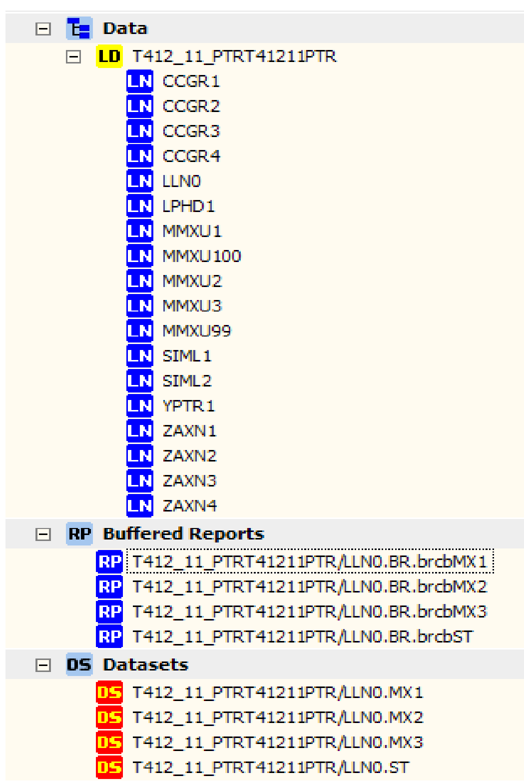

Figure 14**:** Transformer monitoring model for RWE R&D project (3)

The server for the transformer monitoring and the merging unit for the current and voltage samples of the transformer measurements are implemented in a standard PLC – Programmable Logic Controller (see Figure 15).

Figure 15**:** Transformer monitoring and merging unit IEDs

The whole transformer monitoring system is configured through an SCL file defining all needed objects, services, and the binding of the model to the real data of the monitor. The real data values are contained in a database. The binding of the model to the database is accomplished by the so-called <sAddr> attribute in SCL. The binding is automatically done by an interpreter in the IEC 61850 server software.

Once the pilot project is fully functional, protecting, controlling, and monitoring the substation , this is likely the first time where a comprehensive process bus is installed and operating.

9 Web-based and structured access to the IEC 61850 information models

With the use of IEC 61850 in domains outside the substation automation, the number of logical nodes and data objects published is increasing. Today, we have already more than 300 logical nodes defined in different parts of IEC 61850 and IEC 61400-25. There exist many associations between these different documents, but no easy hyperlinked browsing possibility exists. The maintenance of the defined information models always needs to be linked to a new complete document with a large collection of information models.

When experts of new application domains start to use the concepts of IEC 61850 and the existing information models as a base, the domain experts first need to easily identify what already exists. Therefore, it would be preferable to find and browse all information models at one place (preferably at the IEC website).

IEC is supporting the publication of standards as databases – the procedure of the standardization of the information models is defined in Annex J "Procedures for the maintenance of the IEC standards in database format" of the IEC Supplement to ISO/IEC Directives.

It is intended to convert the publication of Logical Nodes and common data classes as being published today in different parts of IEC 61850 and IEC 61400-25 into a web based and structured access solution.

IEC 61850-6, Edition 2 has included in Annex C.2 a XML schema based on SCL type template definitions for the purpose of formally describing IEC 61850 information models as a base to formally document and maintain the models of different IEC 61850 application domains, and facilitate automatic checking of IED data models against these definitions. It is foreseen to describe in the future the standard IEC 61850 information models using that schema. So, in the future, XML documents shall replace the word documents of the parts IEC 61850-7-3 and IEC 61850-7-4xx as well as IEC 61400-25-2 as the normative documents.

Based on these XML documents, several web-based access possibilities can be implemented. Different users need to be able to access the models through a web-based interface:

- Editors of the standard and working group members need to be able to browse existing models, to add new models and to maintain the existing models.
- National committees need to be able to review the draft models and to comment and vote on the models.
- Any interested people shall be able to browse the semantic and details of the models and to download the formal XML documents of the models.

Note that it will still be possible to automatically derive other representations like pdf and html from the XML files.

An example of a Web-based interface to an IEC standard is the Database for IEC 61360:

http://std.iec.ch/iec61360

As part of that work in a first step a Technical Report IEC 61850-7-10 will be prepared that describes the requirements of the different users and the possible approaches for its implementation.

The web-based access and the procedures involved in maintaining the models shall be described in the report and shall be based on Annex J "Procedures for the maintenance of the IEC standards in database format" of the IEC Supplement to ISO/IEC Directives.

10 Conclusions

In highly automated substations and power plants, almost no limitations exist with regard to make the information from the process (status values, measurements, events on limit violations, any monitoring data) available to any entity that needs the information for controlling, monitoring, service, diagnosis, network analyzing, testing, or asset management. The acquisition of any needed process information increases the stability of the system because any failure or trend that may lead to a failure can be made visible.

The electric power delivery system is using IEC 61850, IEC 61400-25, and its extensions in substations, for power quality monitoring applications, for the control and monitoring of wind power plants, control and monitoring of distributed energy resources (DER), and the control and monitoring of hydro power plants.

The condition monitoring possibilities rely on four aspects (standardized in IEC 61850 and IEC 61400-25):

- Standard Data Objects for values to be monitored,
- Standard communication services,
- Fast and reliable communication protocols, and
- Standard configuration language to specify or document the huge amount of information

It is very likely that especially the monitoring applications will be the focus for the next couple of years. Protection and automation of substations is well understood, implemented and used. Many physical aspects are not yet sensed by advanced or even simple sensors.

The standards are providing more and more condition monitoring Data Objects. The services allow for the exchange of these values in real-time (sampled values and GOOSE) as well in client/server relations.

11 References

[1] IEC 61850-1, Communication networks and systems in substations – Part 1: Introduction and overview

[2] IEC 61850-2, Communication networks and systems in substations – Part 2: Glossary

[3] IEC 61850-3, Communication networks and systems in substations – Part 3: General requirements

[4] IEC 61850-4, Communication networks and systems in substations –- Part 4: System and project management

[5] IEC 61850-5, Communication networks and systems in substations – Part 5: Communication requirements for functions and devices models

[6] IEC 61850-6, Communication networks and systems in substations – Part 6: Configuration description language for communication in electrical substations related to IEDs

[7] IEC 61850-7-1, Communication networks and systems in substations – Part 7-1: Basic communication structure for substation and feeder equipment – Principles and models

[8] IEC 61850-7-2, Communication networks and systems in substations – Part 7-2: Basic communication structure for substation and feeder equipment – Abstract communication service interface (ACSI)

[9] IEC 61850-7-3, Communication networks and systems in substations – Part 7-3: Basic communication structure for substation and feeder equipment – Common data classes

[10] IEC 61850-7-4, Communication networks and systems in substations – Part 7-4: Basic communication structure for substation and feeder equipment – Compatible logical node classes and data classes

[11] IEC 61850-8-1, Communication networks and systems in substations – Part 8-1: Specific communication service mapping (SCSM) – Mappings to MMS (ISO/IEC 9506-1 and ISO/IEC 9506-2) and to ISO/IEC 8802-3

[12] IEC 61850-9-1, Communication networks and systems in substations –- Part 9-1: Specific communication service mapping (SCSM) – Sampled values over serial unidirectional multidrop point to point link

[13] IEC 61850-9-2, Communication networks and systems in substations – Part 9-2: Specific communication service mapping (SCSM) – Sampled values over ISO/IEC 8802-3

[14] IEC 61850-10, Communication networks and systems in substations – Part 10: Conformance testing

[15] IEC 61400-25, Wind turbines – Part 25: Communications for monitoring and control of wind power plants

Annex

IEC 61850 and IEC 61400-25 Logical Node Classes

This is an inofficial list compiled by Karlheinz Schwarz, SCC
schwarz@scc-online.de
2010-02-06

Remarks:

Part	Source	Comments
7-4 Ed2 FDIS	LNs_from_57-61850-7-4-draft_FDIS-R0-01_090807	Checked against official FDIS/57/1045. Several LNs from 7-410 have been mo-ved to 7-4 Ed2 FDIS; these will be re-moved from 7-410 Ed2.
7-410 Ed1 IS	LNs_From_FDIS_61850-7-410_2007-02-19.doc	Checked against IS
7-420 Ed1 IS	LNs_From_IEC 61850-420 DER Logical Nodes FDIS June 21, 2008_To-IEC-CO.doc	Checked against IS
61400-25-2 Ed1 IS	LNs_From_88-61400-25-2-PUB-E_Convenor_2006-11-28.doc	Checked against IS

LN Group	#	Clause	Description	Name	Document
L System LNs	1	5.3.2	Physical device information	LPHD	7-4 Ed2 FDIS
	2	5.3.3	Common Logical Node	Common LN	7-4 Ed2 FDIS
	3	5.3.4	Logical node zero	LLN0	7-4 Ed2 FDIS
	4	5.3.5	Physical Communication channel Su-pervision	LCCH	7-4 Ed2 FDIS
	5	5.3.6	GOOSE subscription	LGOS	7-4 Ed2 FDIS
	6	5.3.7	Sampled value subscription	LSVS	7-4 Ed2 FDIS
	7	5.3.8	Time management	LTIM	7-4 Ed2 FDIS
	8	5.3.9	Time master supervision	LTMS	7-4 Ed2 FDIS
	9	5.3.10	Service tracking	LTRK	7-4 Ed2 FDIS
A Automatic Control	10	5.4.2	Neutral current regulator	ANCR	7-4 Ed2 FDIS
	11	5.4.3	Reactive power control	ARCO	7-4 Ed2 FDIS
	12	5.4.4	Resistor control	ARIS	7-4 Ed2 FDIS
	13	5.4.5	Automatic tap changer controller	ATCC	7-4 Ed2 FDIS
	14	5.4.6	Voltage control	AVCO	7-4 Ed2 FDIS
C Control	15	5.5.2	Alarm handling	CALH	7-4 Ed2 FDIS
	16	5.5.3	Cooling group control	CCGR	7-4 Ed2 FDIS
	17	5.5.4	Interlocking	CILO	7-4 Ed2 FDIS
	18	5.5.5	Point-on-wave switching	CPOW	7-4 Ed2 FDIS
	19	5.5.6	Switch controller	CSWI	7-4 Ed2 FDIS
	20	5.5.7	Synchronizer controller	CSYN	7-4 Ed2 FDIS

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D Decentralized Energy Resources	21	5.2.2	DER plant corporate characteristics at the ECP	DCRP	7-420 Ed1 IS
	22	5.2.3	Operational characteristics at ECP	DOPR	7-420 Ed1 IS
	23	5.2.4	DER operational authority at the ECP	DOPA	7-420 Ed1 IS
	24	5.2.5	Operating mode at ECP	DOPM	7-420 Ed1 IS
	25	5.2.6	Status information at the ECP	DPST	7-420 Ed1 IS
	26	5.2.7	DER economic dispatch parameters	DCCT	7-420 Ed1 IS
	27	5.2.8	DER energy and/or ancillary services schedule control	DSCC	7-420 Ed1 IS
	28	5.2.9	DER energy and/or ancillary services schedule	DSCH	7-420 Ed1 IS
	29	5.3.2	DER controller characteristics	DRCT	7-420 Ed1 IS
	30	5.3.3	DER controller status	DRCS	7-420 Ed1 IS
	31	5.3.4	DER supervisory control	DRCC	7-420 Ed1 IS
	32	6.1.2	DER unit generator	DGEN	7-420 Ed1 IS
	33	6.1.3	DER generator ratings	DRAT	7-420 Ed1 IS
	34	6.1.4	DER advanced generator ratings	DRAZ	7-420 Ed1 IS
	35	6.1.5	Generator cost	DCST	7-420 Ed1 IS
	36	6.2.2	Excitation ratings	DREX	7-420 Ed1 IS
	37	6.2.3	Excitation	DEXC	7-420 Ed1 IS
	38	6.3.2	Speed/Frequency Controller	DSFC	7-420 Ed1 IS
	39	7.1.3	Reciprocating Engine	DCIP	7-420 Ed1 IS
	40	7.2.3	Fuel cell controller	DFCL	7-420 Ed1 IS
	41	7.2.4	Fuel cell stack	DSTK	7-420 Ed1 IS
	42	7.2.5	Fuel processing module	DFPM	7-420 Ed1 IS
	43	7.3.3	Photovoltaics module ratings	DPVM	7-420 Ed1 IS
	44	7.3.4	Photovoltaics array characteristics	DPVA	7-420 Ed1 IS
	45	7.3.5	Photovoltaics array controller	DPVC	7-420 Ed1 IS
	46	7.3.6	Tracking controller	DTRC	7-420 Ed1 IS
	47	7.4.3	CHP system controller	DCHC	7-420 Ed1 IS
	48	7.4.4	Thermal storage	DCTS	7-420 Ed1 IS
	49	7.4.5	Boiler	DCHB	7-420 Ed1 IS
	50	7.1.3	Reciprocating Engine	DCIP	7-420 Ed1 IS
	51	7.2.3	Fuel cell controller	DFCL	7-420 Ed1 IS
	52	8.1.3	Fuel delivery system	DFLV	7-420 Ed1 IS
F Functional Blocks	53	5.6.2	Counter	FCNT	7-4 Ed2 FDIS
	54	5.6.3	Curve shape description	FCSD	7-4 Ed2 FDIS
	55	5.6.4	Generic Filter	FFIL	7-4 Ed2 FDIS
	56	5.6.5	Control function output limitation	FLIM	7-4 Ed2 FDIS
	57	5.6.6	PID regulator	FPID	7-4 Ed2 FDIS
	58	5.6.7	Ramp function	FRMP	7-4 Ed2 FDIS
	59	5.6.8	Set-point control function	FSPT	7-4 Ed2 FDIS
	60	5.6.9	Action at over threshold	FXOT	7-4 Ed2 FDIS
	61	5.6.10	Action at under threshold	FXUT	7-4 Ed2 FDIS
	62	7.2.2	Counter	FCNT	7-410 Ed1 IS

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	63	7.2.3	Curve shape description	FCSD	7-410 Ed1 IS
	64	7.2.4	Generic Filter	FFIL	7-410 Ed1 IS
	65	7.2.5	Control function output limitation	FLIM	7-410 Ed1 IS
	66	7.2.6	PID regulator	FPID	7-410 Ed1 IS
	67	7.2.7	Ramp function	FRMP	7-410 Ed1 IS
	68	7.2.8	Set-point control function	FSPT	7-410 Ed1 IS
	69	7.2.9	Action at over threshold	FXOT	7-410 Ed1 IS
	70	7.2.10	Action at under threshold	FXUT	7-410 Ed1 IS
	71	8.4.2	Sequencer	FSEQ	7-420 Ed1 IS
G Generic	72	5.7.2	Generic automatic process control	GAPC	7-4 Ed2 FDIS
	73	5.7.3	Generic process I/O	GGIO	7-4 Ed2 FDIS
	74	5.7.4	Generic log	GLOG	7-4 Ed2 FDIS
	75	5.7.5	Generic security application	GSAL	7-4 Ed2 FDIS
H Hydro Power	76	7.3.2	Turbine - generator shaft bearing	HBRG	7-410 Ed1 IS
	77	7.3.3.	Combinator	HCOM	7-410 Ed1 IS
	78	7.3.4	Hydropower dam	HDAM	7-410 Ed1 IS
	79	7.3.5	Dam leakage supervision	HDLS	7-410 Ed1 IS
	80	7.3.6	Gate position indicator	HGPI	7-410 Ed1 IS
	81	7.3.7	Dam gate	HGTE	7-410 Ed1 IS
	82	7.3.8	Intake gate	HITG	7-410 Ed1 IS
	83	7.3.9	Joint control	HJCL	7-410 Ed1 IS
	84	7.3.10	Leakage supervision	HLKG	7-410 Ed1 IS
	85	7.3.11	Water level indicator	HLVL	7-410 Ed1 IS
	86	7.3.12	Mechanical brake	HMBR	7-410 Ed1 IS
	87	7.3.13	Needle control	HNDL	7-410 Ed1 IS
	88	7.3.14	Water net head data	HNHD	7-410 Ed1 IS
	89	7.3.15	Dam over-topping protection	HOTP	7-410 Ed1 IS
	90	7.3.16	Hydropower / water reservoir	HRES	7-410 Ed1 IS
	91	7.3.17	Hydropower unit sequencer	HSEQ	7-410 Ed1 IS
	92	7.3.18	Speed monitoring	HSPD	7-410 Ed1 IS
	93	7.3.19	Hydropower unit	HUNT	7-410 Ed1 IS
	94	7.3.20	Water control	HWCL	7-410 Ed1 IS
I Interfacing and Archiving	95	5.8.2	Archiving	IARC	7-4 Ed2 FDIS
	96	5.8.3	Human machine interface	IHMI	7-4 Ed2 FDIS
	97	5.8.4	Safety alarm function	ISAF	7-4 Ed2 FDIS
	98	5.8.5	Telecontrol interface	ITCI	7-4 Ed2 FDIS
	99	5.8.6	Telemonitoring interface	ITMI	7-4 Ed2 FDIS
	100	5.8.7	Teleprotection communication interfaces	ITPC	7-4 Ed2 FDIS
	101	7.4.2	Safety alarm function	ISAF	7-410 Ed1 IS
K Mechanical and non-electric primary equipment	102	5.9.2	Fan	KFAN	7-4 Ed2 FDIS
	103	5.9.3	Filter	KFIL	7-4 Ed2 FDIS
	104	5.9.4	Pump	KPMP	7-4 Ed2 FDIS
	105	5.9.5	Tank	KTNK	7-4 Ed2 FDIS
	106	5.9.6	Valve control	KVLV	7-4 Ed2 FDIS
	107	7.5.2	Fan	KFAN	7-410 Ed1 IS
	108	7.5.3	Filter	KFIL	7-410 Ed1 IS
	109	7.5.4	Pump	KPMP	7-410 Ed1 IS
	110	7.5.5	Tank	KTNK	7-410 Ed1 IS
	111	7.5.6	Valve control	KVLV	7-410 Ed1 IS

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M Metering and mea-surement	112	5.10.2	Environmental information	MENV	7-4 Ed2 FDIS
	113	5.10.3	Flicker Measurement Name	MFLK	7-4 Ed2 FDIS
	114	5.10.4	Harmonics or interharmonics	MHAI	7-4 Ed2 FDIS
	115	5.10.5	Non phase related harmonics or in-terharmonics	MHAN	7-4 Ed2 FDIS
	116	5.10.6	Hydrological information	MHYD	7-4 Ed2 FDIS
	117	5.10.7	DC measurement	MMDC	7-4 Ed2 FDIS
	118	5.10.8	Meteorological information	MMET	7-4 Ed2 FDIS
	119	5.10.9	Metering	MMTN	7-4 Ed2 FDIS
	120	5.10.10	Metering	MMTR	7-4 Ed2 FDIS
	121	5.10.11	Non phase related Measurement	MMXN	7-4 Ed2 FDIS
	122	5.10.12	Measurement	MMXU	7-4 Ed2 FDIS
	123	5.10.13	Sequence and imbalance	MSQI	7-4 Ed2 FDIS
	124	5.10.14	Metering Statistics	MSTA	7-4 Ed2 FDIS
	125	7.6.2	Environmental information	MENV	7-410 Ed1 IS
	126	7.6.3	Hydrological information	MHYD	7-410 Ed1 IS
	127	7.6.4	DC measurement	MMDC	7-410 Ed1 IS
	128	7.6.5	Meteorological information	MMET	7-410 Ed1 IS
	129	8.1.2	Fuel characteristics	MFUL	7-420 Ed1 IS
	130	8.5.3	Pressure measurements	MPRS	7-420 Ed1 IS
	131	8.5.4	Heat measured values	MHET	7-420 Ed1 IS
	132	8.5.5	Flow measurements	MFLW	7-420 Ed1 IS
	133	8.5.7	Emissions measurements	MENV	7-420 Ed1 IS
P Protection functions	134	5.11.2	Differential	PDIF	7-4 Ed2 FDIS
	135	5.11.3	Direction comparison	PDIR	7-4 Ed2 FDIS
	136	5.11.4	Distance	PDIS	7-4 Ed2 FDIS
	137	5.11.5	Directional overpower	PDOP	7-4 Ed2 FDIS
	138	5.11.6	Directional underpower	PDUP	7-4 Ed2 FDIS
	139	5.11.7	Rate of change of frequency	PFRC	7-4 Ed2 FDIS
	140	5.11.8	Harmonic restraint	PHAR	7-4 Ed2 FDIS
	141	5.11.9	Ground detector	PHIZ	7-4 Ed2 FDIS
	142	5.11.10	Instantaneous overcurrent	PIOC	7-4 Ed2 FDIS
	143	5.11.11	Motor restart inhibition	PMRI	7-4 Ed2 FDIS
	144	5.11.12	Motor starting time supervision	PMSS	7-4 Ed2 FDIS
	145	5.11.13	Over power factor	POPF	7-4 Ed2 FDIS
	146	5.11.14	Phase angle measuring	PPAM	7-4 Ed2 FDIS
	147	5.11.15	Rotor protection	PRTR	7-4 Ed2 FDIS
	148	5.11.16	Protection scheme	PSCH	7-4 Ed2 FDIS
	149	5.11.17	Sensitive directional earthfault	PSDE	7-4 Ed2 FDIS
	150	5.11.18	Transient earth fault	PTEF	7-4 Ed2 FDIS
	151	5.11.19	Tyristor protection	PTHF	7-4 Ed2 FDIS
	152	5.11.20	Time overcurrent	PTOC	7-4 Ed2 FDIS
	153	5.11.21	Overfrequency	PTOF	7-4 Ed2 FDIS
	154	5.11.22	Overvoltage	PTOV	7-4 Ed2 FDIS
	155	5.11.23	Protection trip conditioning	PTRC	7-4 Ed2 FDIS
	156	5.11.24	Thermal overload	PTTR	7-4 Ed2 FDIS
	157	5.11.25	Undercurrent	PTUC	7-4 Ed2 FDIS
	158	5.11.26	Underfrequency	PTUF	7-4 Ed2 FDIS
	159	5.11.27	Undervoltage	PTUV	7-4 Ed2 FDIS
	160	5.11.28	Underpower factor	PUPF	7-4 Ed2 FDIS
	161	5.11.29	Voltage controlled time overcurrent	PVOC	7-4 Ed2 FDIS
	162	5.11.30	Volts per Hz	PVPH	7-4 Ed2 FDIS

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	163	5.11.31	Zero speed or underspeed	PZSU	7-4 Ed2 FDIS
	164	7.7.2	Rotor protection	PRTR	7-410 Ed1 IS
	165	7.7.3	Thyristor protection	PTHF	7-410 Ed1 IS
Q Power quality events	166	5.12.2	Frequency Variation	QFVR	7-4 Ed2 FDIS
	167	5.12.3	Current Transient	QITR	7-4 Ed2 FDIS
	168	5.12.4	Current Unbalance Variation	QIUB	7-4 Ed2 FDIS
	169	5.12.5	Voltage Transien	QVTR	7-4 Ed2 FDIS
	170	5.12.6	Voltage Unbalance Variation	QVUB	7-4 Ed2 FDIS
	171	5.12.7	Voltage Variation	QVVR	7-4 Ed2 FDIS
R Protection related functions	172	5.13.2	Disturbance recorder channel analogue	RADR	7-4 Ed2 FDIS
	173	5.13.3	Disturbance recorder channel binary	RBDR	7-4 Ed2 FDIS
	174	5.13.4	Breaker failure	RBRF	7-4 Ed2 FDIS
	175	5.13.5	Directional element	RDIR	7-4 Ed2 FDIS
	176	5.13.6	Disturbance recorder function	RDRE	7-4 Ed2 FDIS
	177	5.13.7	Disturbance record handling	RDRS	7-4 Ed2 FDIS
	178	5.13.8	Fault locator	RFLO	7-4 Ed2 FDIS
	179	5.13.9	Differential measurements	RMXU	7-4 Ed2 FDIS
	180	5.13.10	Power swing detection/blocking	RPSB	7-4 Ed2 FDIS
	181	5.13.11	Autoreclosing	RREC	7-4 Ed2 FDIS
	182	5.13.12	Synchronism-check	RSYN	7-4 Ed2 FDIS
	183	7.8.2	synchronising or synchro-check device	RSYN	7-410 Ed1 IS
S Supervision and monitoring	184	5.14.2	Monitoring and diagnostics for arcs	SARC	7-4 Ed2 FDIS
	185	5.14.3	Circuit breaker supervision	SCBR	7-4 Ed2 FDIS
	186	5.14.4	Insulation medium supervision (gas)	SIMG	7-4 Ed2 FDIS
	187	5.14.5	Insulation medium supervision (liquid)	SIML	7-4 Ed2 FDIS
	188	5.14.6	Tap changer Supervision	SLTC	7-4 Ed2 FDIS
	189	5.14.7	Supervision of Operating Mechanism	SOPM	7-4 Ed2 FDIS
	190	5.14.8	Monitoring and diagnostics for partial discharges	SPDC	7-4 Ed2 FDIS
	191	5.14.9	Power Transformer Supervision	SPTR	7-4 Ed2 FDIS
	192	5.14.10	Circuit Switch Supervision	SSWI	7-4 Ed2 FDIS
	193	5.14.11	Temperature supervision	STMP	7-4 Ed2 FDIS
	194	5.14.12	Vibration supervision	SVBR	7-4 Ed2 FDIS
	195	7.9.2	temperature supervision	STMP	7-410 Ed1 IS
	196	7.9.3	vibration supervision	SVBR	7-410 Ed1 IS
	197	8.5.6	Vibration conditions	SVBR	7-420 Ed1 IS
	198	8.5.2	Temperature measurements	STMP	7-420 Ed1 IS
T Instrument Ttransformers and sensors	199	5.15.2	Angle	TANG	7-4 Ed2 FDIS
	200	5.15.3	Axial displacement	TAXD	7-4 Ed2 FDIS
	201	5.15.4	Current transformer	TCTR	7-4 Ed2 FDIS
	202	5.15.5	Distance	TDST	7-4 Ed2 FDIS
	203	5.15.6	Liquid flow	TFLW	7-4 Ed2 FDIS
	204	5.15.7	Frequency	TFRQ	7-4 Ed2 FDIS
	205	5.15.8	Generic sensor	TGSN	7-4 Ed2 FDIS
	206	5.15.9	Humidity	THUM	7-4 Ed2 FDIS
	207	5.15.10	LMedia level	TLVL	7-4 Ed2 FDIS
	208	5.15.11	Magnetic field	TMGF	7-4 Ed2 FDIS
	209	5.15.12	Movement senso	TMVM	7-4 Ed2 FDIS
	210	5.15.13	Position indicator	TPOS	7-4 Ed2 FDIS

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	211	5.15.14	Pressure sensor	TPRS	7-4 Ed2 FDIS
	212	5.15.15	Rotation transmitter	TRTN	7-4 Ed2 FDIS
	213	5.15.16	Sound pressure sensor	TSND	7-4 Ed2 FDIS
	214	5.15.17	Temperature sensor	TTMP	7-4 Ed2 FDIS
	215	5.15.18	Mechanical tension / stress	TTNS	7-4 Ed2 FDIS
	216	5.15.19	Vibration sensor	TVBR	7-4 Ed2 FDIS
	217	5.15.20	Voltage transformer	TVTR	7-4 Ed2 FDIS
	218	5.15.21	Water acidity	TWPH	7-4 Ed2 FDIS
	219	7.10.2	Angle sensor	TANG	7-410 Ed1 IS
	220	7.10.3	Axial displacement sensor	TAXD	7-410 Ed1 IS
	221	7.10.4	Distance sensor	TDST	7-410 Ed1 IS
	222	7.10.5	Flow sensor	TFLW	7-410 Ed1 IS
	223	7.10.6	Frequency sensor	TFRQ	7-410 Ed1 IS
	224	7.10.7	Humidity sensor	THUM	7-410 Ed1 IS
	225	7.10.8	Level sensor	TLEV	7-410 Ed1 IS
	226	7.10.9	Magnetic field sensor	TMGF	7-410 Ed1 IS
	227	7.10.10	Movement sensor	TMVM	7-410 Ed1 IS
	228	7.10.11	Position indicator	TPOS	7-410 Ed1 IS
	229	7.10.12	Pressure sensor	TPRS	7-410 Ed1 IS
	230	7.10.13	Rotation transmitter	TRTN	7-410 Ed1 IS
	231	7.10.14	Sound pressure sensor	TSND	7-410 Ed1 IS
	232	7.10.15	Temperature sensor	TTMP	7-410 Ed1 IS
	233	7.10.16	Mechanical tension /stress sensor	TTNS	7-410 Ed1 IS
	234	7.10.17	Vibration sensor	TVBR	7-410 Ed1 IS
	235	7.10.18	Water pH sensor	TWPH	7-410 Ed1 IS
W Wind Turbines	236	Table 7	Wind turbine general information	WTUR	61400-25-2 Ed1 IS
	237	Table 8	Wind turbine rotor information	WROT	61400-25-2 Ed1 IS
	238	Table 9	Wind turbine transmission information	WTRM	61400-25-2 Ed1 IS
	239	Table 10	Wind turbine generator information	WGEN	61400-25-2 Ed1 IS
	240	Table 11	Wind turbine converter information	WCNV	61400-25-2 Ed1 IS
	241	Table 12	Wind turbine transformer information	WTRF	61400-25-2 Ed1 IS
	242	Table 13	Wind turbine nacelle information	WNAC	61400-25-2 Ed1 IS
	243	Table 14	Wind turbine yawing information	WYAW	61400-25-2 Ed1 IS
	244	Table 15	Wind turbine tower information	WTOW	61400-25-2 Ed1 IS
	245	Table 16	Wind power plant meteorological information	WMET	61400-25-2 Ed1 IS
	246	Table 17	Wind power plant alarm information	WALM	61400-25-2 Ed1 IS
	247	Table 18	Wind turbine state log information	WSLG	61400-25-2 Ed1 IS
	248	Table 19	Wind turbine analogue log information	WALG	61400-25-2 Ed1 IS
	249	Table	Wind turbine report information	WREP	61400-25-2 Ed1

LN Group	#	Clause	Description	Name	Document
		20			IS
	250	Table 21	Wind power plant active power control information	WAPC	61400-25-2 Ed1 IS
	251	Table 22	Wind power plant reactive power control information	WRPC	61400-25-2 Ed1 IS
X Switchgear	252	5.16.2	Circuit breaker	XCBR	7-4 Ed2 FDIS
	253	5.16.3	Circuit switch	XSWI	7-4 Ed2 FDIS
	254	8.3.2	Fuse	XFUS	7-420 Ed1 IS
Y Power transformers	255	5.17.2	Earth fault neutralizer (Petersen coil)	YEFN	7-4 Ed2 FDIS
	256	5.17.3	Tap changer	YLTC	7-4 Ed2 FDIS
	257	5.17.4	Power shunt	YPSH	7-4 Ed2 FDIS
	258	5.17.5	Power transformer	YPTR	7-4 Ed2 FDIS
Z further power system equipment	259	5.18.2	Auxiliary network	ZAXN	7-4 Ed2 FDIS
	260	5.18.3	Battery	ZBAT	7-4 Ed2 FDIS
	261	5.18.4	Bushing	ZBSH	7-4 Ed2 FDIS
	262	5.18.5	Power cable	ZCAB	7-4 Ed2 FDIS
	263	5.18.6	Capacitor bank	ZCAP	7-4 Ed2 FDIS
	264	5.18.7	Converter	ZCON	7-4 Ed2 FDIS
	265	5.18.8	Generator	ZGEN	7-4 Ed2 FDIS
	266	5.18.9	Gas insulated line	ZGIL	7-4 Ed2 FDIS
	267	5.18.10	Power overhead line	ZLIN	7-4 Ed2 FDIS
	268	5.18.11	Motor	ZMOT	7-4 Ed2 FDIS
	269	5.18.12	Reactor	ZREA	7-4 Ed2 FDIS
	270	5.18.13	Resistor	ZRES	7-4 Ed2 FDIS
	271	5.18.14	Rotating reactive component	ZRRC	7-4 Ed2 FDIS
	272	5.18.15	Surge arrestor	ZSAR	7-4 Ed2 FDIS
	273	5.18.16	Semi-conductor controlled rectifier	ZSCR	7-4 Ed2 FDIS
	274	5.18.17	Synchronous machine	ZSMC	7-4 Ed2 FDIS
	275	5.18.18	Thyristor controlled frequency converter	ZTCF	7-4 Ed2 FDIS
	276	5.18.19	Thyristor controlled reactive component	ZTCR	7-4 Ed2 FDIS
	277	7.11.2	Neutral resistor	ZRES	7-410 Ed1 IS
	278	7.11.3	Semiconductor rectifier controller	ZSCR	7-410 Ed1 IS
	279	7.11.4	Synchronous machine	ZSMC	7-410 Ed1 IS
	280	6.4.2	Rectifier	ZRCT	7-420 Ed1 IS
	281	6.4.3	Inverter	ZINV	7-420 Ed1 IS
	282	8.2.2	Battery systems	ZBAT	7-420 Ed1 IS
	283	8.2.3	Battery charger	ZBTC	7-420 Ed1 IS